Fit-Trainer (Smart Knee Sleeve)

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*Abstract*—This electronic document provides background on our Smart Knee Sleeve device also known as Fit-Trainer. The knee sleeve features integrated sensors that monitor joint movement and provide real-time feedback on technique, form, and potential injury risk. The device is also equipped with an app that allows users to track their workouts and receive personalized recommendations for improving their performance. Overall, the smart knee sleeve is a promising tool for optimizing exercise routines and reducing the risk of any injuries.

Keywords—knee, injury, data, performance, workout

# Introduction

Running, squatting, and deadlifting are examples of popular activities that may help people increase their strength, endurance, and general fitness. These activities, however, can place a tremendous pressure on the knee joint, increasing the risk of damage. Knee injuries, such as patellofemoral pain syndrome, meniscus tears, and ligament sprains, can be excruciatingly painful and result in lengthy periods of inactivity, negatively impacting an individual's physical and emotional well-being. To address this problem, a novel smart knee sleeve has been designed with the goal of providing real-time input on technique, form, and injury risk when jogging, squatting, and deadlifting. The smart knee sleeve has embedded sensors and an app that allows users to monitor their joint mobility and receive tailored advice for enhancing their activities.

# Hardware

## Materials

| Materials | Quantity |
| --- | --- |
| Knee Sleeve | 2 |
| Fire Beatle Boards | 2 |
| Fire Beatle Proto Board | 1 |
| Force Sensitive Resistor | 2 |
| Flex Sensor | 1 |
| Accelerometer | 1 |
| Heart Rate Sensor | 1 |
| Battery | 1 |
| Wires | 15 |
| Resistors (10KOhm) | 4 |

## 

Fig. 1 Fit-trainer Device

## Functionality and Design

The device incorporates two distinct sleeves, each housing various sensors and equipment. This design enables seamless monitoring of an individual's heart rate and other vital fitness data. The first knee sleeve features an integrated heart rate sensor, which is achieved by cutting a section of the sleeve and embedding the sensor within. The second knee sleeve is designed to accommodate a Force sensor and additional equipment, intended to be worn on top of the first sleeve. In addition to the sensors housed within the knee sleeves, the device also includes two force-sensitive resistors which are to be placed on the user's shoe sole. These resistors collect data on foot pressure during exercise, providing valuable information on the user's foot placement. This layered approach allows for comprehensive data collection while maintaining wearer comfort. The system is powered by two FireBeetle Board-328P microcontrollers, which communicate wirelessly via Bluetooth to transfer collected data. One of the FireBeetle boards is situated in the first knee sleeve, while the other is connected to a computer for data analysis and visualization. The FireBeetle board housed in the knee sleeve is connected to an array of sensors, including two force-sensitive resistors, one flex sensor, an accelerometer, and a heart rate sensor. This board is powered by a battery, and the force-sensitive resistors and flex sensor are connected to the board through a series of resistors, ensuring accurate and reliable data transmission. By utilizing this advanced knee sleeve system, we can effectively monitor various fitness metrics, providing individuals with valuable insights into their performance and overall health.

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# Software

Fit Trainer is an innovative fitness solution that aims to revolutionize users' workout experiences by providing real-time feedback, comprehensive insights, and customizable options for three core exercises: squats, deadlifts, and cardio. The system leverages cutting-edge technology, such as Force Sensitive Resistors (FSRs) and accelerometers, to empower users in making data-driven decisions, refining their techniques, and ultimately achieving their fitness goals.

## Real-time feedback

## Fit Trainer utilizes advanced sensors, including FSRs and accelerometers, to monitor users' movements and provide instant feedback on their form and technique. This real-time feedback helps users identify and correct any errors or inconsistencies in their movements, ensuring that they are performing each exercise safely and effectively. Additionally, the system offers audio and visual cues to guide users through their workouts, enhancing the overall training experience.

## Start Screen

Upon launching the Fit Trainer app, users are immediately prompted to the user-friendly Start*,* which serves as the

gateway to the various features and functions of the system. It allows users to effortlessly navigate between the three workout options - squat, deadlift, and cardio and initiate their desired exercise with a simple tap. The program's smooth transition to the corresponding exercise tab ensures a seamless user experience. This can be seen in figure 2.

## Squat Tab

The Squat tab incorporates cutting-edge visualization and tracking tools to provide users with real-time performance analysis. The heat map reveals the distribution of foot pressure throughout the squat motion, while a green circle pinpoints the optimal pressure zone to maximize stability and power. This data is collected via two FSRs strategically placed on the user's shoe soles. Additionally, a stick figure animation serves as a visual aid for proper knee movement, and a green line represents the target squat depth for full range of motion. The tab also displays the number of attempted and proper reps,

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encouraging users to maintain correct form for maximum benefits. To further enhance the user's experience, the Squat

tab provides information on eccentric, concentric, and time-at-depth metrics. Users are encouraged to aim for a 1.1-second (or longer) eccentric and concentric time, and a 2.1-second (or longer) time-at-depth to ensure proper muscle engagement and reduce injury risk. This can be seen in figure 3.

## Deadlift Tab

Mirroring the functionality of the Squat tab, the Deadlift tab features an innovative heat map that visualizes foot pressure distribution during the exercise, with a green circle highlighting the ideal pressure zone. A stick figure graphic offers visual guidance on correct knee movement, while a green line signifies the target deadlift depth for a proper rep. The Deadlift tab displays users attempted and proper rep counts, promoting proper form for maximum efficacy. Eccentric, concentric, and time-at-depth metrics are also provided, with the same recommended targets as the Squat tab to guarantee optimal performance and minimize injury potential. This can be seen in figure 4.

## Cardio tab

The Cardio tab delivers a comprehensive overview of the user's cardiovascular workout, essential for those who want to optimize their fitness routine. It includes real-time heart rate data, which allows users to gauge the intensity of their workout and make adjustments as needed. The tab also displays total workout duration, encompassing the entire length of the session, and active workout time, determined using an accelerometer to ensure that only genuine exercise contributes to this metric. A dynamic, easy-to-read heart rate graph is located at the bottom of the screen, offering users a visual representation of their cardiovascular performance throughout the workout. This enables users to identify patterns and trends in their heart rate, helping them maintain their target heart rate zone for maximum fitness benefits. By selecting the 'Insight' button within the Cardio tab, users can delve deeper into their workout trends and records, accessing a more granular analysis of their progress.

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Fig. 5 Fit-trainer Cardio Tab

## Insight Tab

The Insight tab consolidates various performance metrics, such as average heart rate, total calories burned, and distance covered during workouts. These measurements are computed using FSR and accelerometer data to calculate step count, from which caloric expenditure and distance are derived. The tab also displays the user's cadence, or steps per minute, enabling users to monitor and adjust their pacing as needed. A standout feature of the Insight tab is the Cardio Zone classification system, which segments workout intensity into four distinct zones: warmup, fat burn, hardcore, and VO2 max. Time spent in each zone is calculated based on the user's heart rate, assuming a standard age of 21. To facilitate quick interpretation, color-coded, resizable rectangles represent the duration spent in each zone, providing users with a visually engaging snapshot of their workout intensity distribution.

Fit Trainer's combination of sophisticated technology, real-time feedback, and user-friendly interface sets it apart as a comprehensive fitness solution for individuals looking to optimize their exercise routines. By providing personalized insights into performance metrics, form, and intensity, Fit Trainer empowers users to make informed decisions, track their progress, and ultimately achieve their fitness objectives more effectively. This can be seen in figure 6.

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Fig. 6 Fit-trainer Insight Tab

# Further Work and Setbacks

## Social and Community Features

To foster a sense of community and encourage users to stay motivated, Fit Trainer could introduce social features, such as the ability to connect with friends, join workout groups, and participate in challenges. These features could promote healthy competition and support users in maintaining their exercise routines.

## Expanding Futures

Fit Trainer's adaptability ensures that it caters to users with diverse fitness levels and goals. The app could be expanded to include customizable features, such as individualized workout plans, exercise modifications, and personalized recommendations based on users' preferences and performance data. Moreover, future updates to Fit Trainer could integrate additional exercises and workout modalities, such as yoga, high-intensity interval training (HIIT), and strength training, further broadening the app's appeal to a wider audience.

## Challenges Encountered

During the development of the wearable device, several challenges were encountered in both the construction and sensor integration processes. One significant hurdle was the need to create small pockets within the knee sleeves to house sensors and equipment while maintaining user comfort and seamless integration. As a novice at sewing, this task proved to be rather difficult. Additionally, configuring the accelerometer posed substantial challenges due to its complex output of weight values and other data. Furthermore, the force-sensitive resistors and flex sensors were connected to malfunctioning resistors, necessitating their replacement. This process was time-consuming, as it required thorough testing to identify the root cause of the issue, whether it was the resistors or the sensors themselves. Ultimately, the most formidable obstacle faced during this project was ensuring the proper functioning of the accelerometer.

# Conclusion

Fit Trainer presents a comprehensive fitness solution that combines advanced technology, real-time feedback, and an intuitive interface to optimize users' exercise routines. By leveraging an innovative knee sleeve system and incorporating force-sensitive resistors, accelerometers, and other sensors, Fit Trainer provides valuable insights into performance metrics, form, and intensity. Moreover, Fit Trainer's adaptability ensures its relevance for users with diverse fitness levels and objectives. Customizable features and potential future improvements, such as personalized workout plans, exercise modifications, and the inclusion of additional workout modalities, will broaden the app's appeal to a wider audience. Despite the challenges faced during the development of the wearable device, the successful integration of the accelerometer and other sensors has demonstrated the potential of Fit Trainer as an effective and comprehensive fitness solution.

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